Factors associated with in-transit losses of market hogs in Ontario in 2001

Charles Haley, Catherine E. Dewey, Tina Widowski, Zvonimir Poljak, Robert Friendship

Abstract

In-transit losses and stage of transport when deaths occurred were determined for 4 760 213 market-weight pigs produced in 2001 by 4159 Ontario producers and marketed through 117 transport companies to 33 packers located in Canada (96%) and the United States. Approximately 73% and 21% of producers marketed < 2000 pigs and < 500 pigs, respectively. In-transit loss was 0.017%, with 75% of producers losing ≤ 5 pigs annually. Approximately half of in-transit losses occurred on the truck, with 14% of the other deaths occurring at the assembly yards, 4% on the producers' trucks, and 24% at the abattoir. Fifteen percent of in-transit deaths, representing 1212 pigs, occurred in pigs that were previously identified as abnormal by the transporter or personnel working at the assembly yard or abattoir. Average losses were higher for producers marketing < 2000 pigs, and in-transit loss ratio (ITLR) was highest among those marketing < 100 pigs. Pigs from small farms traveled greater distances than those from larger operations. In-transit losses increased sharply between 590 and 720 km traveled, and decreased at distances > 980 km. Environmental temperatures reached ≥ 31°C for 4.2% of pigs shipped in June, July, and August, with median and mean temperatures of 20.6°C and 20.3°C, respectively, for these months. Twenty percent of all in-transit losses (1617 pigs) occurred in August.

Résumé

Les pertes en transit et le moment au cours du transport où le décès est survenu ont été déterminés pour 4 760 213 porcs au poids du marché produits en 2001 par 4159 producteurs ontariens et commercialisés via 117 compagnies de transport à 33 usines situées au Canada (96 %) et aux États-Unis. Environ 73 % et 21 % des producteurs ont commercialisé respectivement < 2000 et < 500 porcs. Les pertes en transit étaient de 0,017 % avec 75 % des producteurs perdant ≤ 5 porcs annuellement. Approximativement la moitié des pertes en transit se sont produites dans le camion, avec 14 % des autres mortalités se produisant dans les enclos de rassemblement, 4 % dans le camion du producteur et 24 % à l'abattoir. Quinze pourcents des mortalités en transit, ce qui représente 1212 porcs, sont survenues chez des porcs qui avaient au préalable été identifiés comme anormaux par le transporteur ou le personnel travaillant aux enclos de rassemblement ou à l'abattoir. Les pertes moyennes étaient plus élevées pour les producteurs commercialisant < 2000 porcs, et la proportion de pertes en transit (ITLR) était plus grande parmi ceux commercialisant < 100 porcs. Les porcs provenant de petites fermes parcouraient des distances plus grandes que ceux provenant d'opérations plus importantes. Les pertes en transit augmentaient brusquement pour les trajets entre 590 et 720 km, et diminuaient pour des distances > 980 km. La température ambiante a atteint ≥ 31 °C pour 4,2 % des porcs expédiés en juin, juillet et août, avec des températures médiane et moyenne respectivement de 20,6 °C et 20,3 °C pour ces mois. Vingt pour cent de toutes les pertes en transit «1617 porcs» se sont produites au mois d'août.

(Traduit par Docteur Serge Messier)

Introduction

"In-transit loss" is a term used to describe pigs that die after leaving the farm but before being stunned at the abattoir. In the past 35 y, these losses have ranged from 0.07% to 5.2% of finishing pigs shipped in different areas of the world, including Canada (1–7). Overall, numbers of pigs lost in transit are generally low relative to the number of pigs shipped, but still cause economic loss due to lost income potential and disposal costs to the producer, transporter, and abattoir. In the past, high transport loss in Europe and North America has been associated with selection for leaner carcasses and, inadvertently, selection for porcine stress syndrome. However, a high proportion of transport loss is believed to be caused by shipping pigs under environmentally adverse conditions (8). In addition, when in-transit loss occurs, it is likely that the transport conditions associated with the deaths of some pigs also caused physiological stress to other pigs in the load, possibly compromising the quality of the pork from these pigs. Therefore, in-transit losses and the conditions associated with these losses may be responsible for more lost revenue to the industry than previously considered. Few studies on in-transit loss have been reported in North America.

Research in Europe has identified the following conditions that lead to in-transit loss: high temperature and humidity; high stocking density; either short or long duration and distance of the trip; and pre-market status in terms of hydration and withdrawal of feed, illness, and genetics (3,4,9–15).

The goals of this study were to assess in-transit losses for market pigs produced in Ontario; to determine the stage of transport when

Department of Population Medicine (Haley, Dewey, Poljak, Friendship), and Department of Animal and Poultry Science (Widowski), University of Guelph, Guelph, Ontario N1G 2W1.

Address all correspondence to Dr. Catherine E. Dewey; telephone: (519) 824-4120, ext. 54746; fax: (519) 763-3117; e-mail: cdewey@uoguelph.ca

Received June 15, 2006. Accepted December 7, 2007.

deaths occur; and to measure the association between in-transit deaths and environmental temperature and humidity, trip distance, farm of origin, transporter company, and abattoir.

Materials and methods

Finisher pigs in Ontario were marketed through the Ontario Pork Producers' Marketing Board (Ontario Pork). The producer contacted personnel at Ontario Pork to tell them how many pigs would be marketed that week. Most pigs were then picked up by a transporter at the farm for delivery to the abattoir. The producer and transporter completed a form for each load of pigs that were loaded onto the truck from the farm. The form included the producer identification number, number of pigs transported, and date. The transporter may travel to several farms to fill the truck before driving to the abattoir. Also, the transporter may travel to one abattoir to unload some pigs and then drive to another abattoir to unload the rest of the pigs. The pigs were counted when they were unloaded, and the original form was signed by a person at the abattoir. Pigs were typically mixed with other pigs in lairage at the abattoir. A small percentage of pigs were transported on the producer's own truck to an assembly yard. A transporter then picked up pigs at the assembly yard to deliver them to the abattoir.

Data that described each load of pigs shipped by each producer for each day in 2001 were provided by Ontario Pork. Each observation included date of shipment, producer's identification number, number of pigs shipped by that producer, number of subject pigs in the group, number of pigs in the group that died in-transit, phase of transport when pigs died, trucking company (transporter), abattoir (packer), and expected time of arrival at the abattoir. Phases of transport included farm, producer's truck, assembly yard, transporter, and abattoir.

Producers, assembly yards, transporters, and abattoirs paid a fee to the in-transit loss account at Ontario Pork for every pig that was marketed or received by them. The money collected in this account was used to compensate producers for pigs that died in-transit. The producer was paid the average pig price for a pig indexing 100 on that day. If a producer, transporter, or abattoir was responsible for higher than average in-transit losses in a given year, the amount paid into the in-transit loss account was increased for the subsequent year. Therefore, it was important to assign responsibility to a specific phase of the in-transit process because of the potential to increase the payment to the in-transit loss account by that individual or company.

A specific data collection form, produced by Ontario Pork, was completed by the producer, assembly yard personnel, transporter, and/or abattoir personnel for every pig that died in-transit. These forms, regulated by Ontario Pork, were required for producers to receive compensation for pigs that died in transit. The phase of transport during which the pig died was considered responsible for the death unless the pig was recognized as being abnormal at an earlier phase. A subject pig form was completed for each pig that was recognized as being abnormal during transport. The form was signed by 2 people along the transport chain including the producer, assembly yard personnel, transporter, and/or abattoir depending on where the pig was recognized as being abnormal. If that pig died in-transit, the point at which the pig was identified as subject was deemed responsible for the death. For example, if a pig was lame at the farm when it was loaded onto the transport truck, the farmer and transporter completed a subject pig form. If the pig subsequently died on the truck or while in lairage at the abattoir, the producer was considered responsible for the loss. Similarly, if a pig is delivered to an assembly yard by the producer and the pig appears abnormal when it is unloaded, it is called a subject pig. If the pig subsequently dies before being stunned at the abattoir, the loss is assessed to the producer's truck.

Computerized data received from Ontario Pork identified each in-transit death and assigned responsibility for that loss. These data were validated by comparing the digital data to the subject pig and in-transit death records completed by the producers, transporters, and abattoir personnel. If more than 1 pig belonging to a producer died in a given transport load, data were recorded for individual pigs.

Hourly dry-bulb and wet-bulb temperatures and relative humidity were obtained from 6 weather stations located near the abattoirs in Ontario and Quebec (16). Documentation regarding the format and units of the data was found on the National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce Web site (17). The weather station was matched to the abattoir by geographic proximity. Two abattoirs in Manitoba, representing 0.08% of the pigs shipped from Ontario in 2001, were not assigned weather data.

Hourly dry-bulb temperature and humidity were received from NOAA for data representing 8 stations in the US that were located near the American plants where Ontario pigs were processed (Scott Stephens, NOAA, personal communication, 2001). Documentation regarding the format and units of the data was found on the National Climatic Data Center Web site (18).

Temperatures were converted from Fahrenheit to Celsius. If the dry-bulb temperature (Tdry) was $\geq 0°F$, wet-bulb temperature (Twet) was calculated from the dry-bulb temperature using the following formula:

$$\text{Twet} = \text{Tdry} - \{0.034\,[\text{Tdry} - (\text{Tdewpoint} \div 10)] - 0.00072\,[\text{Tdry} - (\text{Tdewpoint} \div 10)]\,[\text{Tdry} - (\text{Tdewpoint} \div 10) - 1]\}\,[\text{Tdry} - \text{Tdewpoint} - 2\,(\text{pressure in mmHg})]$$

(Scott Stephens, NOAA, personal communication, 2001). If the dry bulb temperature was $< 0°F$, then the formula used was:

$$\text{Twet} = \text{Tdry} - [0.034\,(\text{Tdry} - \text{Tdewpoint} \div 10) - 0.006\,(\text{Tdry} - \text{Tdewpoint} \div 10)^2]\,[0.6(\text{Tdry} + \text{Tdewpoint}) - 2(\text{pressure in mmHg}) + 108].$$

Humidity was calculated using the following formula:

$$\text{relative humidity} = [173 - 0.1(\text{Tdry}) + \text{Tdewpoint})] \div [173 + 0.9(\text{Tdry})].$$

A temperature-humidity index (pig comfort index), based on the expected impact of temperature and humidity on pigs, was

Table I. Average in-transit loss ratio (ITLR)[a] and ratio of subject pigs[b] by numbers of pigs marketed by each producer and distance travelled by the pigs in Ontario in 2001

Percentile	Category	Percent of pigs per category	ITLR (%)	Subject pigs per pig marketed (%)	Average distance travelled (km)
10	1–100	6.3	0.28	0.002	475
25	101–500	24.8	0.15	0.020	471
50	501–1000	20.9	0.17	0.012	458
75	1001–1500	11.9	0.22	0.023	364
90	1501–2000	8.7	0.23	0.028	327
100	2001–34 704	27.4	0.21	0.032	280

[a] Number of pigs that died in-transit each day divided by the number of pigs marketed.

[b] Subject pigs were identified as abnormal by the transporter or packing plant receiver.

calculated as 0.75(Tdry) + 0.25(Twet) (19). All weather data were merged with the in-transit loss data on the basis of abattoir and expected hour of delivery of the pigs to the abattoir using computer software (SAS, version 8.2; SAS Institute, Cary, North Carolina, USA).

Distance traveled by the pigs was estimated by determining the distance between the transporter's dispatching yard or assembly yard and the abattoir. The number of kilometers between the 2 sites was determined by inserting postal codes for Canadian destinations or zip codes for United States destinations into the distance function on a Web site (20). The distance between the producer's farm (location unknown) and the assembly yard was not included in the distance. Miles were converted to kilometers. Distance information was merged with the in-transit loss data on the basis of transporter and abattoir information.

In-transit loss mortality rate or in-transit loss ratios (ITLR) were calculated for each producer, transporter, and abattoir by dividing the number of pigs that died in-transit each day by the number of pigs that were shipped, transported, or received, respectively. Average ITLR by producer, transporter, abattoir, month of marketing, temperature, humidity, PCI, distance, and number of subject pigs were calculated using computer software (Microsoft Excel; Microsoft Corporation, Redmond, Washington, USA). Monthly ITLR in August were compared to those of other months using a Chi-squared test. Nesting of transporter within abattoir and nesting of producer within transporter and abattoir were also described.

The number of pigs that died per producer per day was modeled using a negative binomial distribution, with the number of pigs marketed by each producer each day as the time component for calculation of the rate of death. Initially, simple associations between in-transit loss and the independent variables of interest were determined. These included number of pigs marketed per producer (increments of 500 pigs) and distance traveled (increments of 50 km). Quadratic and cubic functions of these variables were also tested and retained in the model if $P < 0.05$.

Hierarchical dummy variables were created for the pig comfort index (PCI) variables to identify specific thresholds of this index at which losses increased significantly compared to the previous index (21). This model was built using a backward selection process, eliminating the variable with the highest P value at each step. All significant variables ($P < 0.05$) were entered into a multivariable model with other significant fixed effects and potential interaction terms based on these variables. A backward elimination process was used to remove non-significant variables ($P \geq 0.05$). The fixed effect models were analyzed and tested for goodness of fit, outliers, and leverage using computer software (Stata Statistical, Version 7.0; Stata Corporation, College Station, Texas, USA). Finally, a Poisson general linear mixed effects model using a Glimmex macro in SAS was performed, including producer, transporter, and abattoir as random variables. Variables with $P > 0.05$ were eliminated from these models. The intraclass correlation coefficient (ICC) was calculated using a null model containing only random variables.

Results

This study included all 4 760 213 market-weight pigs produced in 2001 by 4159 Ontario producers and marketed through 117 transport companies (transporters) to 33 abattoirs located in Canada and the USA. Approximately 4% of pigs were processed in the USA, 82% remained in Ontario, 13% went to Quebec, and 0.08% went to Manitoba (data not shown). In-transit loss was 0.17% (17 pigs per 10 000 marketed). Most producers (75%) who experienced in-transit losses lost ≤ 5 pigs during the entire year. More than half (57%) of the in-transit losses occurred on the transporter's truck, 4% occurred at arrival to the assembly yard while on the producers' truck, 14% occurred at the assembly yard, and 24% at the abattoir.

The subject pig classification was maintained in the records only if the pig died or was euthanized prior to processing. Fifteen percent of pigs that died in transit were classified as subject before death. This accounted for 1212 pigs or 0.025% of all pigs marketed. Most subject pigs (88%) were identified by the transporter and abattoir as they were being unloaded from the transporter's truck at the abattoir.

The ITLR was based on the annual number of pigs marketed per producer, transporter, and abattoir. Producers marketing < 100 pigs had the highest annual ITLR (Table I). Approximately 73% of Ontario producers marketed < 2000 pigs and 21% marketed < 500 pigs. Pigs marketed by producers with small operations traveled greater distances than pigs marketed by larger producers (Table I). Approximately 3% of trucking companies shipped ≥ 37 000 pigs and 30% shipped > 270 000 pigs. The distances

Table II. Factors associated with in-transit loss ratio for Ontario market pigs in 2001, with impact measured as incidence rate ratio (IRR) based on a Poisson general linear mixed random effects model

Fixed effect	IRR[a]	$S_{\bar{x}}$	P
Pig comfort index[b]			
10 to < 14	1.13	0.203	< 0.0001
14 to < 16	1.25	0.046	0.01
16 to < 19	1.24	0.064	< 0.001
19 to < 22	1.56	0.061	< 0.001
22 to < 26	1.26	0.048	< 0.0001
26 to < 32	2.06	0.044	< 0.0001
32 to < 33	1.48	0.046	< 0.0001
33 to 33.6	0.13	0.122	< 0.01
Pigs marketed (500-pig increments)	1.02	0.357	< 0.0001
Pigs marketed (500-pig increments)	1.00	0.014	0.21
Pigs marketed (500-pig increments)	1.00	0.001	0.02
Distance (50-km increments)	1.13	< 0.001	0.01
Distance (50-km increments)	1.00	0.031	< 0.001
Random effect	Variation due to random variables	$S_{\bar{x}}$	P
Producer[c]	0.54	0.029	< 0.0001
Transporter[c]	0.17	0.044	< 0.0001
Abattoir[c]	0.35	0.132	< 0.01
Error term	1.08	0.004	< 0.0001

[a] IRR — Incidence rate ratio for a given hierarchical range of pig comfort indexes, the incidence rate for death is approximately the IRR times the incidence rate of death for next lower range.
[b] Pig comfort index = 0.75 (dry-bulb temperature in °C) + 0.25(wet-bulb temperature°C) (19).
[c] Producer, transporter, and abattoir included in the model as random variables.

traveled for 75%, 50%, 25%, and 10% of all trucks were < 726 km, < 201 km, < 141 km, and < 104 km, respectively.

Dry temperatures reached ≥ 31°C for only 4.2% of pigs shipped in June, July, and August. Median and mean temperatures for the 3 mo were 20.6°C and 20.3°C, respectively. Weather conditions were most extreme in August, with a maximum temperature of 33.6°C and an average PCI of 22.1. In-transit loss ratios were 0.16%, 0.29%, 0.24%, 0.40%, and 0.17% in May, June, July, August, and September, respectively. August had the highest in-transit losses per month of the year and accounted for 20% of the total annual losses (1617 pigs) ($P < 0.0001$).

The producer cluster explained the highest proportion of the random variation in in-transit losses after accounting for fixed effects. The producer, abattoir, and transporter were responsible for 25%, 16%, and 8% of the total random variation, respectively (Table II). The producer-level ICC was 0.23 (determined by the null model with no fixed effects).

The incidence rate ratio used as the outcome measurement for the fixed effects in the multivariable model was a measurement of animal time, specifically, the number of pigs that died in-transit and shipped by a given producer divided by the number of pigs in that shipment owned by that producer. There was an association between in-transit losses and an index of temperature and humidity (Figure 1). The predicted incidence rate ratio (IRR) for pig deaths in a given PCI hierarchical range is the coefficient multiplied by the incidence rate for pig deaths in the range that follows. For example, the IRR for pig deaths in the PCI range between 19 and 21 is 1.56 times greater than that for pig deaths in the PCI range between 16 and 18. These coefficients are additive, therefore the ITLR in the PCI range of 19 to 21 is 2.8 times greater than that in the PCI range of 14 to 15.

The IRR for continuous variables reflects the increase in the IRR of in-transit loss for each 1-unit increase in the independent variable. As the number of pigs marketed annually increased by 500-pig units, the in-transit losses increased to approximately 3360 pigs, then leveled off at approximately 3890 pigs per year before decreasing (Figure 2). There was also a curvilinear relationship between the distance traveled and the predicted in-transit losses. There was a slight increase in in-transit losses between 70 and 590 km; losses increased sharply between 590 and 720 km and then decreased at distances greater than approximately 980 km (Figure 3).

No observations were removed from the analysis as a result of analysis of outliers, leverage cases, or influential cases identified.

Discussion

Of the 4.7 million pigs marketed in Ontario in 2001, 16.7 pigs per 10 000 marketed (approximately 0.17%) died in-transit. This ITLR is similar to those recorded in the previous 10 y, which range from 0.08% to 0.15% (1,2,4,6,7,15,22–24). This study, based on all pigs marketed in Ontario in 2001, provides a more complete record of in-transit losses in a population than an earlier study in Europe in which in-transit loss was measured at individual abattoirs

IRR [a]	DT	Humidity %																			
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
	10	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	10	10	10	10	10
Ref. Group [b]	11	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10	11	11	11	11	11
	12	10	10	10	10	10	10	10	11	11	11	11	11	11	11	11	12	12	12	12	12
	13	10	11	11	11	11	11	11	11	12	12	12	12	12	12	12	13	13	13	13	13
1.13	14	11	11	12	12	12	12	12	12	13	13	13	13	13	13	13	14	14	14	14	14
	15	12	12	13	13	13	13	13	13	14	14	14	14	14	14	14	14	15	15	15	15
	16	13	13	13	14	14	14	14	14	14	15	15	15	15	15	15	15	16	16	16	16
	17	14	14	14	15	15	15	15	15	15	16	16	16	16	16	16	16	17	17	17	17
1.25	18	15	15	15	15	16	16	16	16	16	17	17	17	17	17	17	17	18	18	18	18
	19	16	16	16	16	17	17	17	17	17	17	18	18	18	18	18	18	19	19	19	19
1.24	20	17	17	17	17	18	18	18	18	18	18	19	19	19	19	19	19	20	20	20	20
	21	18	18	18	18	18	19	19	19	19	19	20	20	20	20	20	20	21	21	21	21
	22	18	19	19	19	19	20	20	20	20	20	21	21	21	21	21	21	22	22	22	22
	23	19	20	20	20	20	20	21	21	21	21	22	22	22	22	22	22	23	23	23	23
1.56	24	20	20	21	21	21	21	22	22	22	22	22	23	23	23	23	23	24	24	24	24
	25	21	21	22	22	22	22	23	23	23	23	23	24	24	24	24	24	25	25	25	25
	26	22	22	23	23	23	23	24	24	24	24	24	25	25	25	25	25	26	26	26	26
1.26	27	23	23	23	24	24	24	24	25	25	25	25	26	26	26	26	26	26	27	27	27
	28	24	24	24	25	25	25	25	26	26	26	26	27	27	27	27	27	27	28	28	28
	29	25	25	25	26	26	26	26	27	27	27	27	27	28	28	28	28	28	29	29	29
	30	25	26	26	26	27	27	27	28	28	28	28	28	29	29	29	29	29	30	30	30
	31	26	27	27	27	28	28	28	28	29	29	29	29	30	30	30	30	30	31	31	31
2.06	32	27	28	28	28	29	29	29	29	30	30	30	30	31	31	31	31	31	32	32	32
	33	28	28	29	29	29	30	30	30	31	31	31	31	32	32	32	32	32	33	33	33
	34	29	29	30	30	30	31	31	31	32	32	32	32	33	33	33	33	33	34	34	34
	35	30	30	31	31	31	32	32	32	33	33	33	33	34	34	34	34	34			
	36	31	31	32	32	32	33	33	33	33	34	34	34								
	37	32	32	32	33	33	33	34	34	34											
	38	32	33	33	34	34	34														
1.61	39	33	34	34																	
	40	34																			

Outside range of observed values

Figure 1. Incremental increases in pig comfort index (PCI), expressed as incidence rate ratios (IRR[a]), that were associated with the ratio of in-transit deaths of pigs marketed per producer per day in Ontario in 2001. The PCI is a weighted average of dry temperature (DT) in degrees Celsius (75%) and wet bulb temperature (25%) (19).

[a] **IRR is the increase expected for each category compared to the category above it in the figure.**
[b] **Ref. Group is the reference category to which all other categories are compared. However, increases are additive, for example, the 3rd IRR category from the top, representing temperatures of 19°C to 22°C has an IRR that is 3.62 times the IRR of the referent group. These models were developed using a Glimmex macro (SAS, version 8.2; SAS Institute, Cary, North Carolina, USA) and included total pigs shipped by the producer for 2001 and distance travelled to market as fixed effects, with producer, transporter, and abattoir as random variables.**

(1,2–4,25,26). Studies of this type have been conducted in the USA, but were limited to individual abattoirs or trucking companies (7). Two Canadian studies also include clinical trials (6,22).

In-transit losses were higher in the summer months compared with the rest of the year; the highest mean and maximum daily temperatures and highest in-transit losses occurred in August. Other researchers have found an association between high temperatures and in-transit loss (1,26–29). The combination of high temperature and high humidity reduces the ability of pigs to dissipate body heat effectively through radiative, convective, or evaporative means (30). Under these conditions, core body temperature cannot be regulated and metabolic acidosis and cardiovascular failure ultimately develop (31).

In this study, in-transit losses and the PCI were associated. Roller and Goldman (19) developed the PCI to describe the effects of temperature and humidity on the pig's ability to regulate internal temperature. As environmental temperature approaches body temperature, maintenance of core temperature in homeotherms depends on evaporative cooling mechanisms, which are less effective in high humidity conditions (19,30). Pigs do not sweat sufficiently to cool themselves; therefore, without an external source of water for evaporation from body surfaces, they must rely exclusively on panting for evaporative cooling. Respiratory evaporation is generally less affected by relative humidity than is evaporation from external skin surfaces. Thus, in contrast to humans, pigs are more sensitive to high dry temperature than high humidity, and dry temperature is weighted more heavily than humidity in the PCI.

This study identified PCI cut points that were associated with higher in-transit losses. For example, at a relative humidity of 60%, the incidence rate of predicted deaths in-transit was 5.9 times higher at 26°C to 31°C than at 16°C to 18°C. Providing fans on trucks, shipping at night, and reducing pig density on trucks might reduce in-transit deaths during extremes of temperature and humidity (6,28,32,33), but laws preventing delivery to abattoirs at certain hours

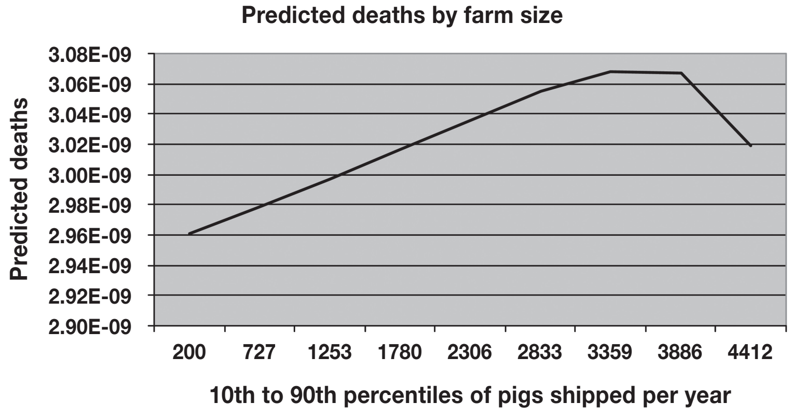

Figure 2. Relationship of farm size to predicted in-transit losses[a] based on the poisson regression model after controlling for pig comfort index and distance travelled, and the random effects of farm, transporter, and abattoir, in Ontario, 2001.

[a] Predicted deaths represent the in-transit loss ratio represented as exponential notation (E) with a base of 10.

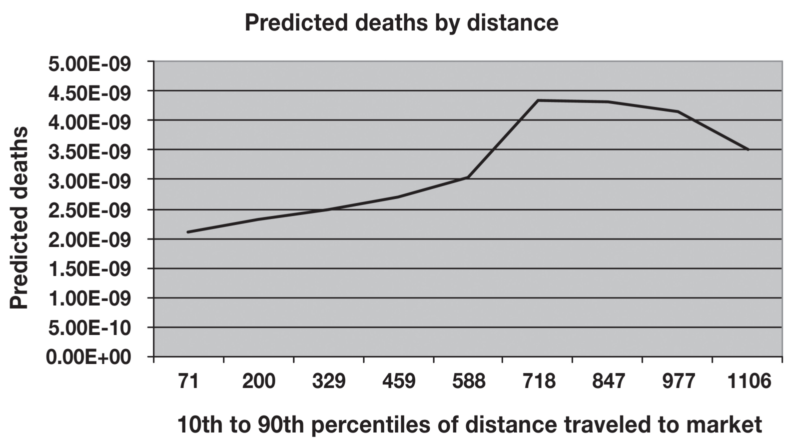

Figure 3. Relationship of farm size to predicted in-transit losses[a] based on the poisson regression model after controlling for pig comfort index and farm size, and the random effects of farm, transporter, and abattoir, in Ontario, 2001.

[a] Predicted deaths represent the in-transit loss ratio represented as exponential notation (E) with a base of 10.

and costs to transporters when they ship with fewer pigs may make these modifications difficult to implement.

Although 57% of pigs died on the transporter's truck, transporters were responsible for only 16% of the random variation in in-transit loss. Random farm effect explained 25% of the total unexplained variation in in-transit losses. Although this study was not designed to identify specific farm factors associated with loss, other researchers have identified putative factors, including high lean genetics, handling techniques, moving strategies, shipping procedures and facilities, feed restriction, degree of mixing, hydration status, and management in the finisher (4,9,33–36). This study did evaluate the effect of farm size on losses. In-transit losses increased as the farm size increased up to 3360 pigs marketed per year, with no further increases in losses for larger farm sizes. However, as farm size was measured in 500-pig increments, the impact of small farms (< 400 pigs) was not captured. Shipments from the same farm on different marketing days were moderately correlated, as measured by the intraclass correlation coefficient, suggesting a consistent influence of farm management style on in-transit losses. These factors warrant further study in the Ontario pork industry.

There was a curvilinear association between distance traveled and in-transit losses. Losses increased as distance increased by 50 km increments. Losses increased sharply between 590 km and 720 km and then remained fairly constant until 980 km at which point the losses decreased. Distance traveled seems to have a protective effect in trips of approximately 10 h or more (980 to 1100 km). Previous research has suggested associations of carcass quality compromise and behavior with short trips (1 to 4 h), moderately long trips (4 to 8 h), and extremely long trips (> 24 h) (9,11,25,28,29,37,38). However, no published reports of the effect of trip duration on in-transit loss were found.

Inherent limitations exist when pre-existing data is used for a research project. Producer, transporter, abattoir, date, pigs sold per producer per day, farm size, and pigs that died in transport were likely accurate, because these are the fundamental components of payment for pigs in Ontario. Distance may have been underestimated, as distance from farm of origin to assembly yard was not included. Temperature and humidity approximated the environment experienced by the pigs, but reflected only the expected time of arrival at the processing plant, as data were not collected during the trip.

Temperature experienced by pigs during shipping is an important risk factor for death in-transit. Shipping at night would be a good solution. However, transport companies may be unwilling to ship at this time, and abattoirs located in cities or residential neighborhoods may not be allowed to receive pigs at night. A balance must be achieved between economic constraints and the welfare of shipped pigs.

References

1. Allen WM, Hebert CN, Smith LP. Deaths during and after transport of pigs in Great Britain. Vet Rec 1974;94:212–214.
2. van Logtestijn JG, Romme AMTC, Eikelenboom G. Losses caused by transport of slaughter pigs in the Netherlands. Transport of Animals Intended for Breeding, Production and Slaughter. Vol. 18. London: Martinus Nijhoff, 1981:105–114.
3. Warriss PD. Choosing appropriate space allowances for slaughter pigs transported by road: A review. Vet Rec 1998;142:449–454.
4. Warriss PD. The welfare of slaughter pigs during transport. Anim Welf 1998;7:365–381.
5. Warriss PD, Bevis EA, Edwards JE, Brown SN, Knowles TG. Effect of the angle of slope on the ease with which pigs negotiate loading ramps. Vet Rec 1991;128:419–421.
6. Whiting TL, Brandt S. Minimum space allowance for transportation of swine by road. Can Vet J 2002;43:207–212.
7. Zanella AJ, Duran O. Pig Welfare During Loading and Transportation: A North American Perspective. Proceedings of the 1st International Virtual Conference on Pork Quality: Welfare, transport, slaughter and consumers. Conferência Virtual Internacional sobre Qualidade de Carne Suína, 2001:12.
8. Geers R, Bleus E, Van Schie T, et al. Transport of pigs different with respect to the halothane gene: Stress assessment. J Anim Sci 1994;72:2552–2558.
9. Abbott TA, Guise HJ, Hunter EJ, Penny RHC, Easby C. Factors influencing pig deaths during transit: An analysis of driver's reports. Anim Welf 1995;4:29–40.
10. Bradshaw RH, Hall SJ, Broom DM. Behavioural and cortisol response of pigs and sheep during transport. Vet Rec 1996;138: 233–234.
11. Bradshaw RH, Parrott RF, Forsling ML, et al. Stress and travel sickness in pigs: Effects of road transport on plasma concentrations of cortisol, beta-endorphin and lysine vasopressin. Anim Sci 1996;63:507–516.
12. Bradshaw RH, Parrott RF, Goode JA, Lloyd DM, Rodway RG, Broom DM. Behavioural and hormonal responses of pigs during transport: Effect of mixing and duration of journey. Anim Sci 1996;62:547–554.
13. Hunter EJ, Weeding CM, Guise HJ, Abbott TA, Penny RHC. The effect of season and stocking density on pig welfare during transport. Appl Anim Behav Sci 1994;41:274.
14. Kettlewell PJ, Hampson CJ, Green NR, Teer NJ, Veale BM, Mitchell MA. Heat and moisture generation of livestock during transportation. Transactions of the ASAE. American Society of Agricultural Engineers. Livestock Environment VI. 2001:519–526.
15. Lambooij E, van Putten G. Transport of pigs. In: Grandin T, ed. Livestock Handling and Transport. 1st ed. New York: CAB International, 1993:213–231.
16. Environment Canada. Climate Data Online. [page on the Internet]. c 2008. Available from http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html Last accessed May 8, 2006.
17. National Oceanic and Atmospheric Administration. U.S. Department of Commerce. [homepage on the Internet]. Available from www.noaa.gov/climate.html Last accessed May 8, 2006.
18. Dataset Documentation. NOAA Satellite and Information Service, National Climatic Data Center. [page on the Internet]. c 2008. Available from http://www4.ncdc.noaa.gov/ol/documentlibrary/datasets.html Last accessed May 9, 2006.
19. Roller WL, Goldman RF. Response of swine to acute heat exposure. Trans ASAE 1969;12:164–169,174.
20. MapQuest. [homepage on the Internet]. c 2008. Available from http://www.mapquest.com Last accessed May 9, 2006.
21. Walter SD, Feinstein AR, Wells CK. Coding ordinal independent variables in multiple regression analyses. Am J Epidemiol 1987;125:319–323.
22. Clark EG. Necropsy survey of transport stress deaths in Saskatchewan market weight hogs. Proc Am Assoc Vet Lab Diag 1979:53–60.
23. Guardia MD, Gispert M, Diestre A. Mortality rates during transport and lairage in pigs for slaughter. Meat Focus Int 1996; 5:362–365.
24. Warriss PD, Brown SN, Edwards JE, Anil MH, Fordham DP. Time in lairage needed by pigs to recover from the stress of transport. Vet Rec 1992;131:194–196.
25. Palacio J, Garcia-Belenguer S, Gascon FM, et al. Pig mortality during transport to an abattoir. Investigación Agraria, Producción y Sanidad Animales 1996;11:159–169.
26. Smith LP, Allen WM. A study of the weather conditions related to the death of pigs during and after their transportation in England. Agric Meteor 1976;16:115–124.
27. Christensen L, Barton-Gade P, Blaabjerg LO. Investigation of transport conditions in participating countries in the EC Project: PL 920262. Proc 40th International Congress of Meat Science and Technology. 1994.
28. Lambooy E, Engel B. Transport of slaughter pigs by truck over a long distance: some aspects of loading density and ventilation. Livest Prod Sci 1991;28:163–174.
29. Lambooy E, van der Hel W, Hulsegge B, Brandsma HA. Effect of environmental temperature and air velocity two days preslaughtering on heat production, weight loss and meat quality in non-fed pigs. Energy Metabolism in farm animals. Effects of housing stress and disease. MWA Verstegen and AM Henken (eds). Martinus Nijhoff, Dordrecht. 1987:164–179.
30. Schrama JW, van der Hel W, Gorssen J, Henken AM, Verstegen MW, Noordhuizen JP. Required thermal thresholds during transport of animals. Vet Q 1996;18:90–95.

31. Marple DN, Jones DJ, Alliston CW, Forrest JC. Physiological and endocrinological changes in response to terminal heat stress in swine. J Anim Sci 1974;39:79–82.
32. Barton-Gade P. The effect of different stocking densities during transport on pig welfare. 46th International Congress of Meat Science and Technology. 2000:134–135.
33. Guise HJ, Penny RH. Transport of pigs. Vet Rec 1996;138:339.
34. Beattie VE, O'Connell NE, Kilpatrick DJ, Moss BW. Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. Anim Sci 2000;70: 443–450.
35. de Jong IC, Prelle IT, van de Burgwal JA, et al. Effects of rearing conditions on behavioural and physiological responses of pigs to preslaughter handling and mixing at transport. Can J Anim Sci 2000;80:451–458.
36. Geverink NA, Kappers A, van de Burgwal JA, et al. Effects of regular moving and handling on the behavioral and physiological responses of pigs to preslaughter treatment and consequences for subsequent meat quality. J Anim Sci 1998;76:2080–2085.
37. Lambooy E. Watering pigs during road transport through Europe. Fleischwirtsch 1983;63:1456–1458.
38. Riches HL, Guise HJ, Penny RHC, Jones TA, Cuthbertson A. A national survey of transport conditions for pigs. Pig J 1997; 38:8–18.